International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249–6890; ISSN (E): 2249–8001
Vol. 11, Issue 4, Aug 2021, 147-156

Original Article

CORRELATION ANALYSIS BETWEEN ENERGY EFFICIENCY AND ENERGY MANAGEMENT AT A CEMENT PLANT USINGCORRELATIONAL ANALYSIS

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ABSTRACT

Since the end of the 9th century, energy efficiency has become an important research topic. Indeed, energy efficiency measures have been identified as among the most valuable means to reduce the harmful impact of climate change. However, in South Africa, the adoption of energy efficiency measures is due to the urgent need to reduce the detrimental effects of climate change and critical energy scarcity. Therefore, this study looks at the relationship between the current practices of energy management, the implementation of energy efficiency measures and the acceptance of energy-efficient measures within cement plants using correlational analysis to increase the performance of energy at South African cement plants. In addition, this study used inferential statistical analysis to establish respondents' perceptions based on their job descriptions.

This study employed a quantitative-type methodology with 55 questionnaires designed and administered to the production and engineering departments. In an attempt to represent the cultural character of the target respondents, 15 questionnaires were delivered through email address, and 40 questionnaires were distributed to the plant's workers with a request to partake in the survey. The inferential analysis shows a difference in the job title of the respondents and the energy manager awareness within the plant with a significance value of p = 0.036. While the inferential result fromthe energy manager awareness and energy efficiency policy, the chi-square p-values showed no critical relationship between respondents' views with a value of 0.263.

KEYWORDS: Cement Plant, Energy Efficiency, Energy Management, Correlational Analysis & Chi-Square Test

Received: Apr 27, 2021; **Accepted**: May 17, 2021; **Published**: Jun 18, 2021; **Paper Id**.: IJMPERDAUG202112

1. INTRODUCTION

Energy efficiency is now becoming the most crucial area in recent years. In the early 1990s, scientists began to vigorously discuss the relationship between climate change and the energy resource's effective use. The demand for energy resource conservation is different from the need for growth. Some researchers believe that it is difficult to achieve significant growth without using energy resources [1]. Therefore, there is a need to find an appropriate balance between energy use and development. The agreement between the international communities is that every nation bears responsibility for sustainable energy resources. African countries and especially South Africa must also participate in this global effort.

The cement industry is well-known for consuming a large percentage of total energy resources used in industries, which is estimated between 30 % and 40 % in several countries. Cement production processing consumes various energy sources, comprising thermal energy, heat, or electrical energy. The energy required to produce Portland clinker ranges from 3 to 6 MJ/kg clinker, depending on the raw materials and processes used. The thermal energy used in the cement production process accounts for roughly 90 % of overall specific energy use,

with the primary fuel obtains from petcoke, coal, natural gas, fuel, and other notable alternative fuels, for instance, animal wastes and biomass. Due to its current energy-demanding nature, the cement plant usually responsible for 50 % to 60 % of the total cost of production [2], while thermal energy contributes about 20 % to 25 % of the cement production cost [3].

1.1 Energy use in a South Africa Cement Plant

Consumption of energy relating to the cement plants varies considerably in terms of electricity use, plant capacity, and the plant's operations. Some plants are engaged in the cement production process only, while others contract the entire cement production process, i.e., from raw materials extraction to cement product. The megawatt-hours of electricity used by cement plants in South Africa range from 55 MWh to 194 MWh per year [4]. Figure 1 shows the primary energy-demanding sections within the cement production process. The figure shows that the grinding circuit process consumes an average of 100 to 120 kWh / ton of electricity [5, 6].

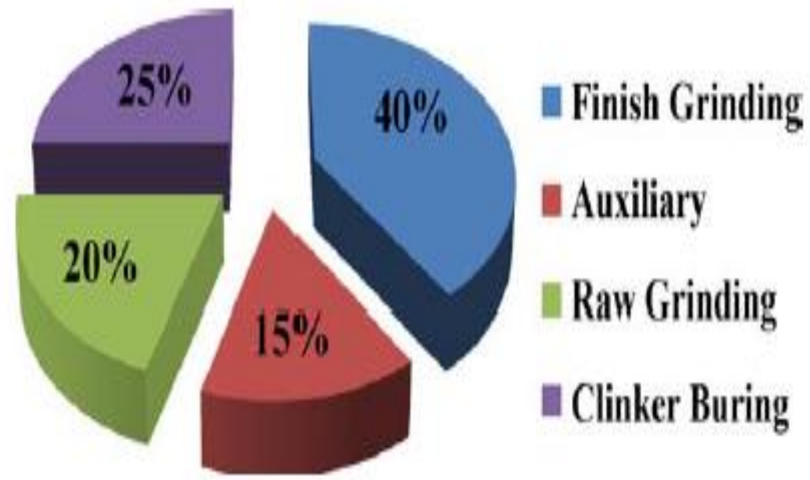

Figure 1: Energy Distribution of Cement Production Sections [5].

The grinding sections used about 60 % of the energy, as shown in Figure 1. These sections use thermal energy supplied by kilns coal-fired and electricity to power the fans, drive the motors and conveyor systems. The total electricity used in the grinding circuit represents 75 % of the total energy used by average cement production. The energy used in a cement production process is equivalent to 50 % to 60 % of the total cost of production, of which electricity responsible for 18 % to 43 % [7]. In a typical cement plant, electricity accounts for 13 % of the total energy inputs; however, it accounts for almost half of the total energy cost [8].

1.2 South Africa Demand-Side Management

Eskom, an electricity company own by the South African government, has launched many innovative indications to manage and monitor the country's limited energy supply effectively. Demand Side Management (DSM) is one of the initiatives to manage change in the demand context. Eskom intends to change the country's electricity demand configuration policy by providing the customers with full electricity implementation and supervision under the DSM program. In addition, the DSM intends to reduce and modify the country's electricity demand profile by installing energy-saving technologies [9].

1.3 CO_2 Emissions from Cement Plants in South African

South Africa is the 13th largest emitter of carbon dioxide (CO_2) worldwide. This emission is likely to increase as our targets improve. In addition to energy costs, CO2 emission and other greenhouse gases (GHG) emissions are significant in environmental protection worldwide. Nearly 33 % of global emissions are energy consumption related, and cement plants are responsible for about 7 % of CO_2 emissionsglobally [10, 11]. Since 1950, CO_2 emissions from burning fossil fuels in South Africa have risen about seven times, and coal alone accounts for up to 93 % of total CO_2 emissions [12].According to Müller and Harnisch [13], global emissions from cement plants contribute 5 % to 8 % CO_2. Mwakasonda [14] reported that South Africa contributed nearly 1.44 % of the world's CO_2 equivalent, while sub-Saharan regions contribute 40 % to 60 % of all CO_2 emissions.

The continuous increases in the fossil fuels cost and deterioration in the quality of the global environment have prompted energy policymakers to formulate policies aimed at reducing energy demand and dependence on fossil fuels. However, increasing demand for electricity, global energy demand, and usage is increasing [15]. "Energy efficiency" and "energy management" are two powerful energy approaches for decreasing the energy resources negative impact. Energy efficiency is a method of managing and restraining the growth in energy use. Energy efficiency reduces the production cost and increases environmental advantages by reducing GHG emissions and air pollution [16]. Energy management means controlling and improving energy by employing systems and techniques to reduce energy needs per production unit while maintaining or lowering the system's overall production costs [17].

1.4 South Africa Cement Plant Energy Management

Energy management in cement plants is critical, and education policies and are necessary to accomplish this. Energy management is essential in South Africa because, as previously mentioned, the country is among the leading emitters of CO_2 globally and consumers of fossil fuels for energy. Understanding the energy required for different components/sections of cement production is critical for efficient management of the entire cement production process.

According to McKane [18], industrial energy management is generally hindered by many factors such as:

- Absence of information inside the plant.
- Management with insufficient skill.
- Lack of knowledge among the workers about the advantages of energy efficiency measures and initiatives.
- Cultural or financial limitations that give priority to invest in production capacity than energy efficiency measures.
- Treating upfront costs as a priority over energy costs.

According to Mohd [19], energy management is a method rationally used by management and technologists to enhance the organization's energy efficiency. Bunse, et al. [20]define energy management in academic research as controlling energy efficiency, monitoring, and improving performance. Kok, et al. [21] state that energy efficiency measures are relevant because of resource shortage and global warming. Kannan and Boie [22] define energy management as a reasonable use of energy to increase profits and improve the position of an organization competitive. In the production process, energy efficiency optimization, profit, and effectiveness are factors for establishing business achievement.

Therefore, energy efficiency is the current common policy goal of many countries globally [23].

As Ottermann [24] suggests, the cement industry's effectiveness will depend on cement plants' ability to manage their energy resources effectively. Industrial energy consumers must recognize that energy management will result in significant cost savings and an extension of the equipment life cycle as well as plant expansion without new capital expenditures by using existing equipment more effectively [25]. The energy management in Industries can assist South Africa to grow their economies through increased industrialization. In addition, it can help generate extra energy resources and thus further develop the country's economy.

2. THE BENEFITS OF ENERGY EFFICIENCY

The European Environment Agency (EEA) highlighted many other benefits of accepting energy efficiency such as promoting social, economic, and environmental growth, as shown in figure 2Barbu, et al. [26]. The most significant benefits of the study are as follows: environmental benefits by reducing GHGs and local pollution, reducing energy demand and therefore the price of energy, natural resource protection, job creation, improving consumer welfare, increasing in competitiveness, reduction in investments energy infrastructure, and participation to enhance energy security [26, 27]. Figure 2 illustrates the 15 critical benefits of improving energy efficiency, which is helpful worldwide and essential to the current South Africa energy crisis [28].

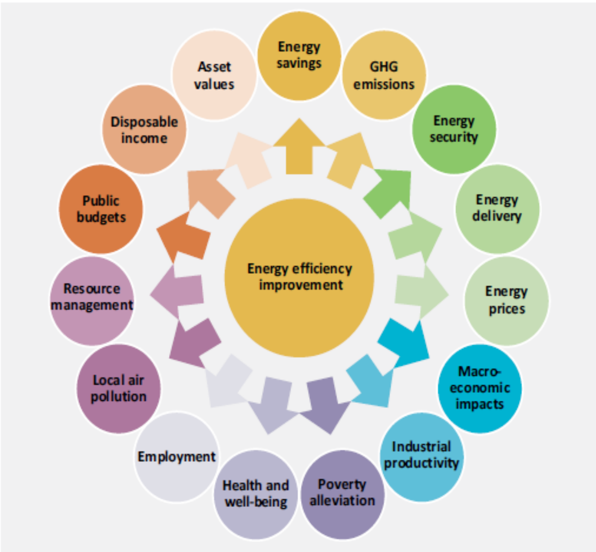

Figure 2: Multiple Benefits of Energy-Efficiency Improvements [28].

This literature review considers energy efficiency mainly as a tool to mitigate climate change, improve energy savings, and improve energy security. There is no doubt that the acceptance of energy efficiency is "the fastest and the cheapest way to address energy security, environmental and economic challenges"[29].

3. DEFINITION OF CORRELATIONAL ANALYSIS

A correlational analysis is a statistical tool used to determine a relationship between two variables/data sets and how deep the connection is. Also, a correlation analysis is used in market research to look at quantitative data acquired through research methods like surveys and polls to see any crucial relationships, patterns, or trends between the two. The aim of

correlational research is to determine how closely variations in one feature or variable are related to variations in one or more other features or variables [30]. When one variable (X) increases and another variable (Y) increases or decreases, there is a correlation. There is no correlation between the variables studied when an analysis returns a correlation coefficient of 0.00.

3.1 Chi-Square Statistic

The chi-square test of independence (also called the Pearson chi-square test) is a crucial statistic for evaluating hypotheses when the variables are minor, as is generally the case in scientific research. The chi-square (χ^2) may provide comprehensive information on the importance of any observed differences and present detailed information about the exact category responsible for the differences discovered.The designs required to calculate the chi-square give essential details about how each group behaves in a study. This detail intensity helps the researcher understand the results and obtain comprehensive and correct information via this statistic rather than trying to make sense of a large number of other data.

4. RESEARCH METHODS

This study mainly used quantitative research methods, with respondents completing a questionnaire. The technique was chosen because it was suitable to attain a correlated set of features that influence energy efficiency improvement. The fieldwork was done in one of South Africa's oldest cement plants between the 1st of March and 30th of May 2017.

The quantitative research method, including correlational studies,is used to collect data on quantitative, facts, and correlations that have been achieved via a detailed process. The aim is to develop and apply mathematical models, hypotheses, and theories that affect the facts. The measurement process in this work is essential because it provides the primary connection between practical observations and the correlations of mathematical methods. Quantitative approaches justify arguments with numbers and statistics, as well as theories that provide explanations. This method is significant since quantitative sampling generates statistical data that allows the overview of results concerning the target population [31].The results and conclusions of the quantitative study are based on statistical analysis

Standardized questionnaires are used when information is required on a population's characteristics, behaviour, and attitudes [32].Davies and Hughes [33] stated that questionnaires are often used to gather critical information. A questionnaire allows the respondent to think through the question before making an immediate answer. Since it is a more anonymous format, a questionnaire will enable respondents to share their opinions. There were open-ended and closed questions for different respondents.

This survey aimed to establish the current industrial energy management practice in cement grinding plants by investigating the level of implementation and acceptance of energy efficiency awareness within the plant. Fifty-five questionnaires in total were distributed to the production engineering department to represent the diversity of the cultural character of the target respondents; 15 questionnaires were delivered through email addresses, and 40 were distributed to the staff that willing to take part in the survey. The case study plant did not have an energy efficiency manager; therefore, the questionnaires were distributed among the managers and engineering workers working in the energy-related area. Seventeen respondents have answered the questionnaire, 16 males and one female.

The questionnaire was in two sections. The first section gathered to date on the profile of the respondents regarding their awareness of an energy efficiency manager in the plant, while the second section was designed to capture the understanding, awareness and behaviour of the respondents regarding the plant energy efficiency policy, using the chi-

square test analysis.

Therefore, the amount of information and the level of detail that this statistical information can provide makes it one of the most useful of the range of analytical tools available to researchers. However, as for every statistic, there are conditions for its proper use, known as "assumptions" of the statistic. Furthermore, the χ^2 is an important test that should always be used with a suitable strength test.

5. RESULT AND DISCUSSIONS

5.1 Correlational Analysis

Correlational research establishes relationships between two or more variables in the same population or between the same variables [30].

Data were recorded based on the job title to determine if respondents were aware of the existence of an energy manager and the connection between plant respondents' job title and awareness of the position of an energy manager within the plant. The job descriptions of respondents were classified as Managerial or Technical positions. Managerial roles were assigned to respondents who worked within the chain of command of several departments and in administrative positions. Technical officeholders are employees that work as engineering workers within the plant. The respondents' data on awareness of the availability of energy efficiency managers and energy efficiency policy was coded into a yes or no response.

5.2 The Energy Manager Awareness among the Staff

Table 1: Respondent Job Title and Awareness of Energy Manager.

Energy Manager Awareness within the Plant	Position/ Title in Plant				
	Managerial	Technical	Total		
Yes	4	1	5		
No	3	9	12		
Total	7	10	17		
Chi-Square Tests Analysis					
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	4.408[a]	1	.036		
Continuity Correction[b]	2.430	1	.119		
Likelihood Ratio	4.535	1	.033		
Fisher's Exact Test				.101	.060
N of Valid Cases[b]	17				

According to Table 1, 5 out of 17 respondents know that the plant employed an energy manager. Four are part of the chain of command within the management roles from five optimistic respondents in the plant. The remaining 12 responders, on the other hand, were not aware that the plant did not have an energy manager. These four respondents represent 57.1% of the total seven responders within the plant's managerial role and 23.5% of the total respondents in the sample. Table 1 shows that 9 out of 10 respondents in the technical job title do not know who responsible for energy efficiency.

An inferential statistical analysis was carried out using the chi-square test to investigate if there was a correlation between the respondents' job title and awareness of an energy manager within the plant (see Table 1). The study assumed

that there was no difference in respondents' awareness of an energy manager in the plant and chi-square analysis was used to assess this. The results are shown in Table 1 and the critical value is 0.036 with a significance value is less than 0.05 according to the analysis. Therefore, the study rejects the insignificant assumption and accepts the other assumption which state that respondents' job title and awareness of an energy manager in the plant differ significantly.

5.3 Awareness of Energy Efficiency Policy among the Staff

Table 2: Respondent Job Title and Awareness of Energy Efficiency Policy

Awareness of Energy Efficiency Policy within the Plant	Position/Title in Plant				
	Managerial Position	Technical Position	Total		
Yes	4	3	7		
No	3	7	10		
Total	7	10	17		
Chi-Square Tests Analysis					
	Value	**df**	**Asymp. Sig. (2-sided)**	**Exact Sig. (2-sided)**	**Exact Sig. (1-sided)**
Pearson Chi-Square	1.252[a]	1	.263		
Continuity Correction[b]	.382	1	.536		
Likelihood Ratio	1.257	1	.262		
Fisher's Exact Test				.350	.268
N of Valid Cases[b]	17				

According to Table 2, 7 out of 17 respondents know that the plant has an energy efficiency policy. The remaining 10 respondents, on the other hand, had no idea of the plant's energy efficiency policies. Out of 7 positive respondents in the plant, 4 responders are part of the management roles chain of command. I It can then be assumed that people in managerial positions are more familiar with the availability of energy efficiency policies because they often meet the management. These four respondents represent 57.2% of the total seven responders within the plant's managerial role and 42.85% of the total respondents in the sample. However, the chi-square test results showed that this difference was not significant.

An inferential statistical analysis was performed using the chi-square test to determine the respondents' job title and their awareness on the plant’s energy efficiency policy (see Table 2). The study assumed that there was no difference in respondents' awareness about the plant's energy efficiency policy and chi-square analysis was used to evaluate. Table 2 shows that the results have a p-value of 0.263, which is higher than 0.05 and thus not significant. The result of the chi-square p-value means that the insignificant assumption is accepted and there is no substantial difference in the respondents' views between managerial and technical jobs regarding energy efficiency policy awareness.

6. CONCLUSIONS

This paper presents an overall correlation between energy efficiency and management practices in a South African cement finishing mill plant using the chi-square test. In addition, the study promotes energy efficiency improvement in the cement plant.

The data received on the awareness of the respondents from the plant on availability of energy efficiency manager was coded into yes or no response, and the result shows that 1 out of 10 respondents within the technical departmental job description in the plant was not aware of the availability of an energy efficiency manager in the plant. The result from chi-square analysis showed a substantial difference in the perception of respondents on an energy efficiency manager in the

plant, with a p-value of **0.036.** This statement can be explained by the fact that respondents in the technical department do not have much contact with the efficiency manager and their job description.

The data on the energy efficiency policy awareness among respondents and their correlation between plant respondent's job title and perception of energy efficiency policy showed that 7 out of the 17 respondents were aware that the plant had an energy efficiency policy. The remaining 10 respondents, on the other hand, had no idea of the plant's energy efficiency policies.Out of the 7 positive responders, 4 were part of the plants within the managerial role. From the chi-square analysis, the study found no difference in the job description of respondents' and their perception of energy efficiency policy within plant, with a p-value of **0.263.**

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